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SOLVENT EXTRACTION OF GOLD FROM LEACH SLURRY
FINAL REPORT OF TRAINING AT CANMET

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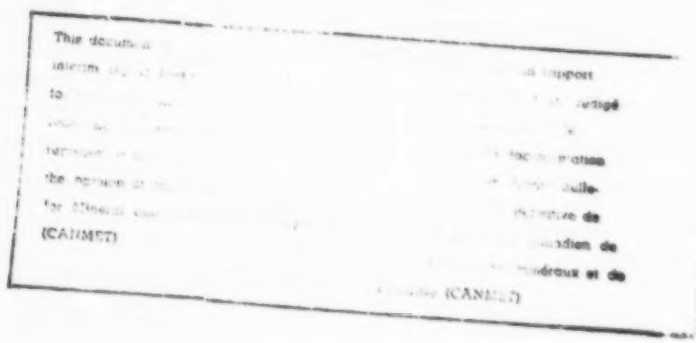

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by

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ABSTRACT

This report summarizes work carried out as part of the IAEA training programme. All the testwork was performed in connection with a project examining the solvent-in-pulp extraction of gold from a cyanide leach slurry. The slurry was characterized in terms of particle size. Settling tests were carried out using various flocculants. Polyox WSR was identified as the best settling agent. Bench tests were done to investigate organic losses in slurry contact using a quaternary amine extractant. Agitation was identified as one of the most important parameters determining the amount of organic lost on the solid particles. Extraction kinetics was examined. The work terminated with preliminary pilot-plant testing of a modified Graesser type contactor for solvent-in-pulp extraction of gold with Aliquat 336 using a real feed slurry.

Keywords: Solvent-in-pulp, Flocculant, Gold extraction, Quaternary amine.

EXTRACTION PAR SOLVANT DE L'OR CONTENU DANS LES BOUILLIES DE LIXIVIATION
RAPPORT FINAL SUR UN STAGE DE FORMATION À CANMET

par

Xifeng Gao et R. Molnar

RÉSUMÉ

Le présent rapport fait état des travaux réalisés en vertu du programme de formation de l'Agence internationale de l'énergie atomique (AIEA). Tous les essais ont été effectués dans le cadre d'un projet de recherche sur l'extraction par solvant en pulpe de l'or contenu dans une bouillie de lixiviation cyanurée. La bouillie a été caractérisée en fonction de la dimension des particules. Des essais de sédimentation ont été menés au moyen de divers floculants. Le Polyox WSR a été identifié comme étant le meilleur agent de sédimentation. Un contrôle au banc d'essai a été fait en utilisant un solvant d'extraction à l'amine quaternaire en vue de déterminer l'importance des pertes organiques dans la bouillie. L'agitation a été identifiée comme l'un des paramètres les plus utiles pour déterminer l'importance de la perte organique dans les particules solides. La cinétique de l'extraction a fait l'objet d'une étude. Les travaux ont pris fin avec l'essai à l'échelle-pilote d'une mise de contact modifiée de type Graesser pour l'extraction par solvant en pulpe de l'or avec Aliquat 236, au moyen d'une véritable bouillie d'alimentation.

INTRODUCTION

In the past few decades many attempts have been made to recover gold from alkaline cyanide solution by solvent extraction processes. Various extractants have been tried. Research workers at CANMET have also conducted investigations on this subject in recent years and have made some encouraging progress. Solvent extraction has many advantages over other extraction processes. Gold is extracted by some extractants both efficiently and selectively. The contact time required to reach equilibrium for solvent extraction is much shorter than that for activated carbon absorption and ion exchange. Solvent extraction has received more and more attention in the hydrometallurgy of gold. It will probably be used under certain circumstances in the future as an alternative industrial method for gold recovery from alkaline cyanide leach solutions.

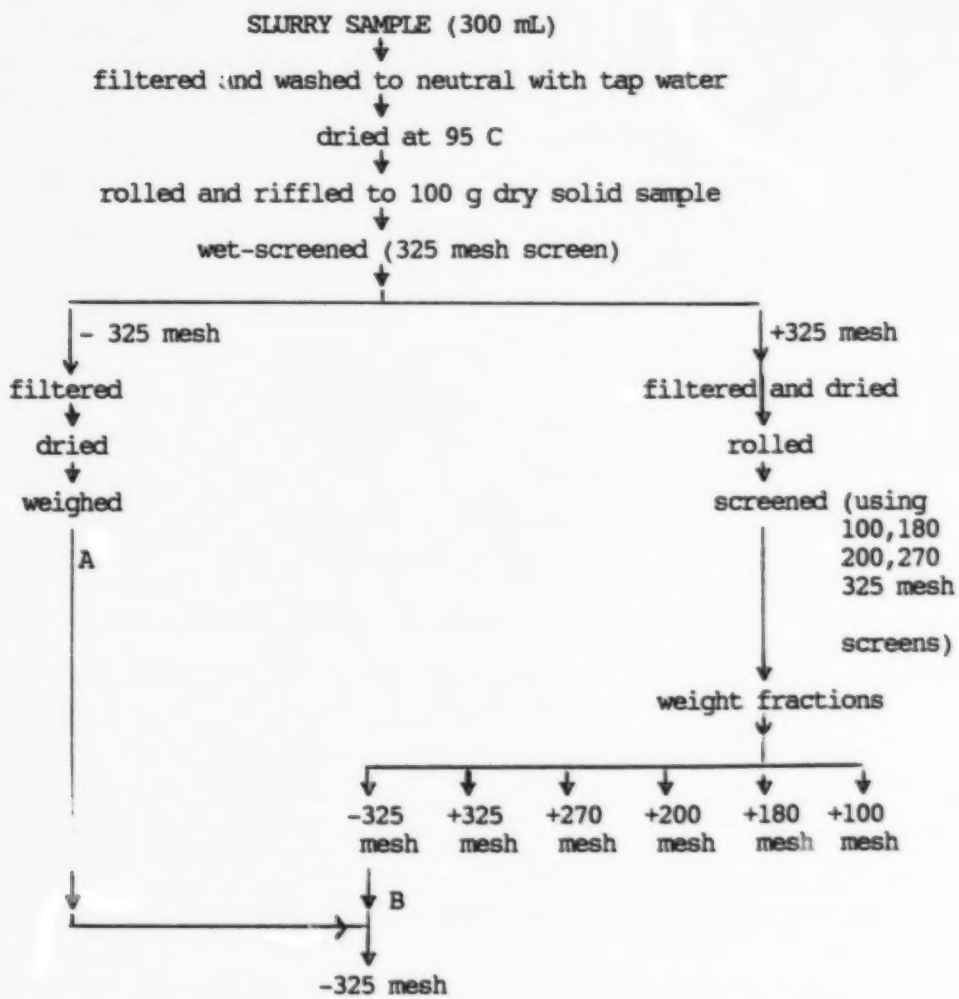
I was sent by IAEA to Canada to be trained at CANMET. The duration of my Fellowship was six months (from April 13 to October 11, 1987). During the training period there was no specific project on uranium extraction in progress in the Solution Purification Section of the Extractive Metallurgy Laboratory of CANMET, but a research programme on the solvent extraction of gold was being carried on. When I came here some investigations had been completed and the optimum conditions for gold extraction had been determined. It had also been decided to carry out an investigation on solvent extraction of gold from leach slurry (SIP). As I knew, our mill in China would treat gold-bearing ores in the near future, it should be extremely valuable for me to gain as much knowledge about gold extraction as possible. Therefore I chose the SIP project. In the past six months, our SIP group has finished several tests and obtained some preliminary results. This report summarizes the test work we have done and the main results we have obtained.

SLURRY SAMPLE AND ITS PHYSICAL PROPERTIES

The slurry we used in our tests was alkaline cyanide leach slurry received from the flotation tailings circuit of Campbell Red Lake Mine,

Canada, on Jan 24, 1987. The specific gravity of dry solids obtained from the slurry was measured to be 2.426. The particle size distribution was determined by screening analysis using 300 mL of the slurry sample according to the following procedure:

Screen Analysis Procedure



Screen Analysis Result

particle size (mesh)	weight (g)	content (%)	cumulative (%)
+100	3.41	3.41	3.41
-100 +150	6.74	6.74	10.15
-150 +200	10.82	10.82	20.97
-200 +270	9.09	9.09	30.06
-270 +325	4.03	4.03	34.09
-325	65.91	65.91	100
TOTAL	100	100	100

SETTLING AND FLOCCULATION TEST

We found that the solid particles in the gold slurry settled extremely slowly because of very fine particle sizes and rather high slurry density (about 45%). In order to increase the settling rate we tried the following seven different flocculants and one surfactant:

Flocculant	Ionic type
Dow Separan M 266	Cationic
" MG 205	Non-Ionic
" MG 700	Anionic
Allied Colloid Percol 351	Non-Ionic
" Percol 155	Anionic
Polyox WSR coagulant	Non-Ionic
Cyanamid Superfloc N-300	Non-Ionic
Alchem 8A04	Surfactant

The results of the settling tests (in the table and Figures 1 and 2) show that of the additions we used the coagulant Polox WSR is the most effective and its dosage is very low, only 25 grams per tonne of solids.

Settling Test Results
(Settling Times min.sec or h:min)

Test	1	2	3	4*	5	6	7	8	9	10	11	12	13
Reagent g/t	MG205 50	NONE 0	M-266 50	MG700 50	P-351 50	P-155 50	WSR 50	N-300 50	WSR 25	WSR 50	WSR 50	WSR 100	8AO4 31b/T
Initial (mL)	100	102	102.5	100	102.5	102	104	103	99	102	103.5	104	99
Height (cm)	18.5	18.6	18.7	17.5	18.9	19.2	18.5	19.0	18.7	18.5	19.1	19.1	19.0
100	0	2.50	3.00	0	1.50	1.10	1.47	3.15	0	1.40	2.03	4.45	-
97.5	1.55	8.20	9.50	0.50	4.30	3.30	3.46	6.22	1.10	3.22	5.35	9.10	7.30
95	3.35	15.00	15.30	1.15	7.50	5.30	5.06	9.04	2.40	5.05	6.25	13.25	16.35
92.5	5.25	23.15	23.50	-	9.10	7.30	6.40	12.37	4.30	6.45	8.20	18.00	26.10
90	7.50	30.30	30.45	3.30	11.10	9.20	8.05	14.47	6.05	8.10	10.10	22.40	34.45
87.5	9.35	37.30	37.30	-	13.20	11.15	10.35	16.35	7.55	10.00	12.00	27.10	43.10
85	10.40	44.40	43.45	5.35	-	13.00	11.52	18.47	9.30	11.30	13.50	31.35	57.35
82.5	11.10	52.10	50.30	-	17.15	14.40	13.40	21.22	11.10	13.10	15.40	36.00	61.40
80	12.20	58.30	56.45	7.25	19.10	16.15	15.05	23.24	12.50	14.35	17.20	40.20	70.50
77.5	14.10	65.10	63.45	-	20.50	-	16.35	26.00	14.20	16.20	19.25	44.30	78.25
75	15.05	71.20	69.30	-	22.50	19.30	17.55	28.00	15.55	17.45	21.25	48.45	87.40
72.5	-	77.45	76.10	-	24.45	21.20	19.27	30.24	17.30	19.20	23.10	53.00	95.40
70	17.10	83.50	82.15	-	27.10	23.10	20.50	32.38	18.50	20.50	25.00	57.00	03.10
67.5	20.05	90.15	87.30	11.55	29.40	25.15	22.30	35.12	20.25	22.35	26.55	61.15	09.55
65	22.10	96.10	94.15	13.45	32.30	29.55	23.05	37.26	21.40	23.55	28.50	65.20	16.20
62.5	25.30	1:42	1:40	17.50	36.30	32.15	24.40	40.54	23.15	25.40	31.05	64.45	33.30
60	29.30	~2:	2:00	23.10	41.20	36.45	26.10	47.48	24.35	27.05	33.45	73.45	68.00
57.5	39.45	~2:30	2:30	35.15	59.15	56.15	28.10	-	26.00	29.00	48.05	78.20	80.00
55	60.15	~3:	~3:	64.30	~2:15	2:15	30.40	1:57	27.40	31.05	1:50	83.00	-
52.5	1:49	~3:20	~3:30	-	~3:	-	41.30	-	40.20	37.05	-	1:55	-
50	-	-	-	-	-	-	-	-	44.00	65.30	-	-	-
Final(mL)	50.0	48.1	48.7	53.0	51.3	52.1	49.0	51.6	49.5	49.0	53.2	50.1	53.5

Final Volume is after settling for 16 hours.

* Cloudy Supernatant

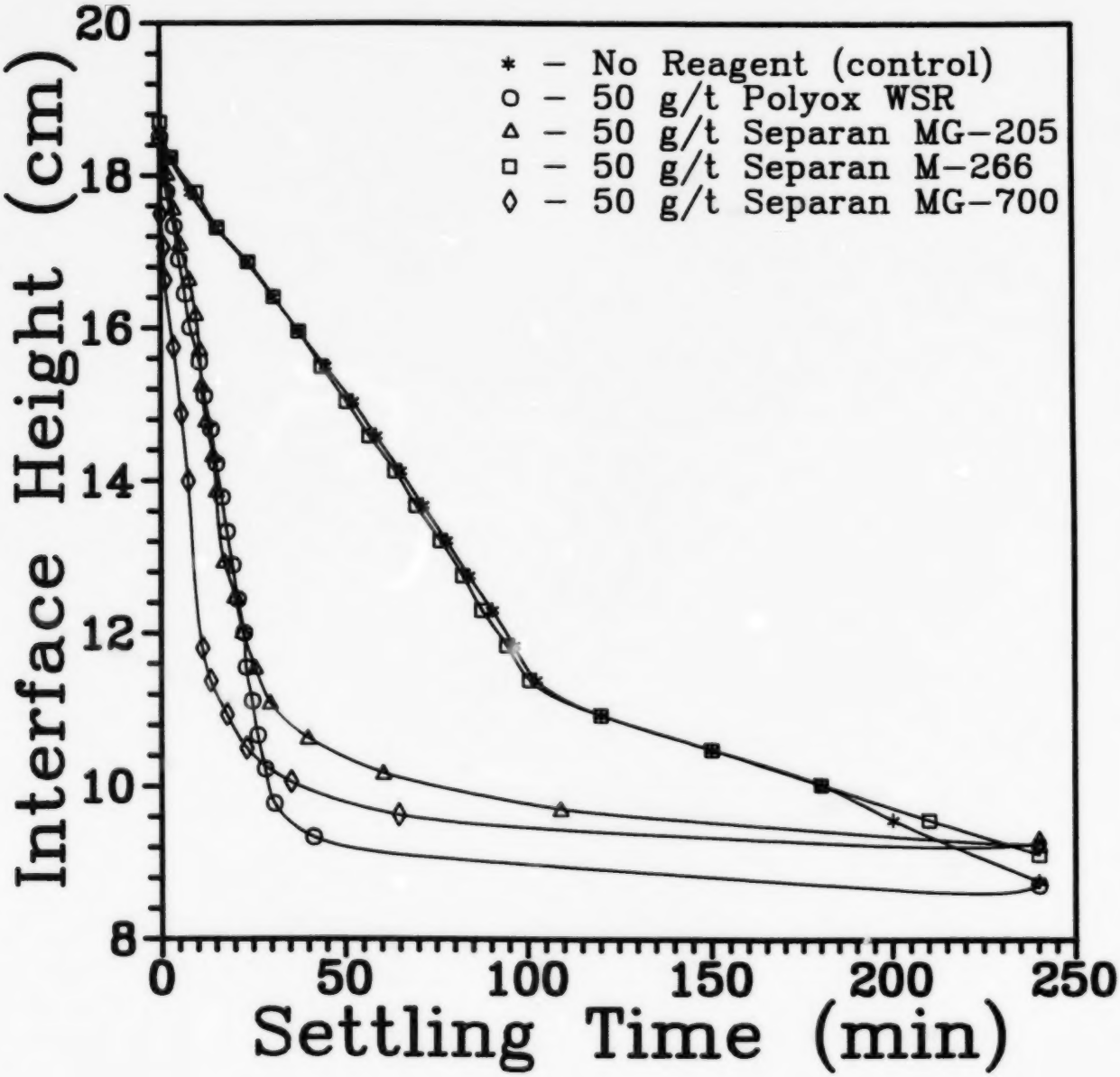


Figure 1. Settling Curves for Different Additives

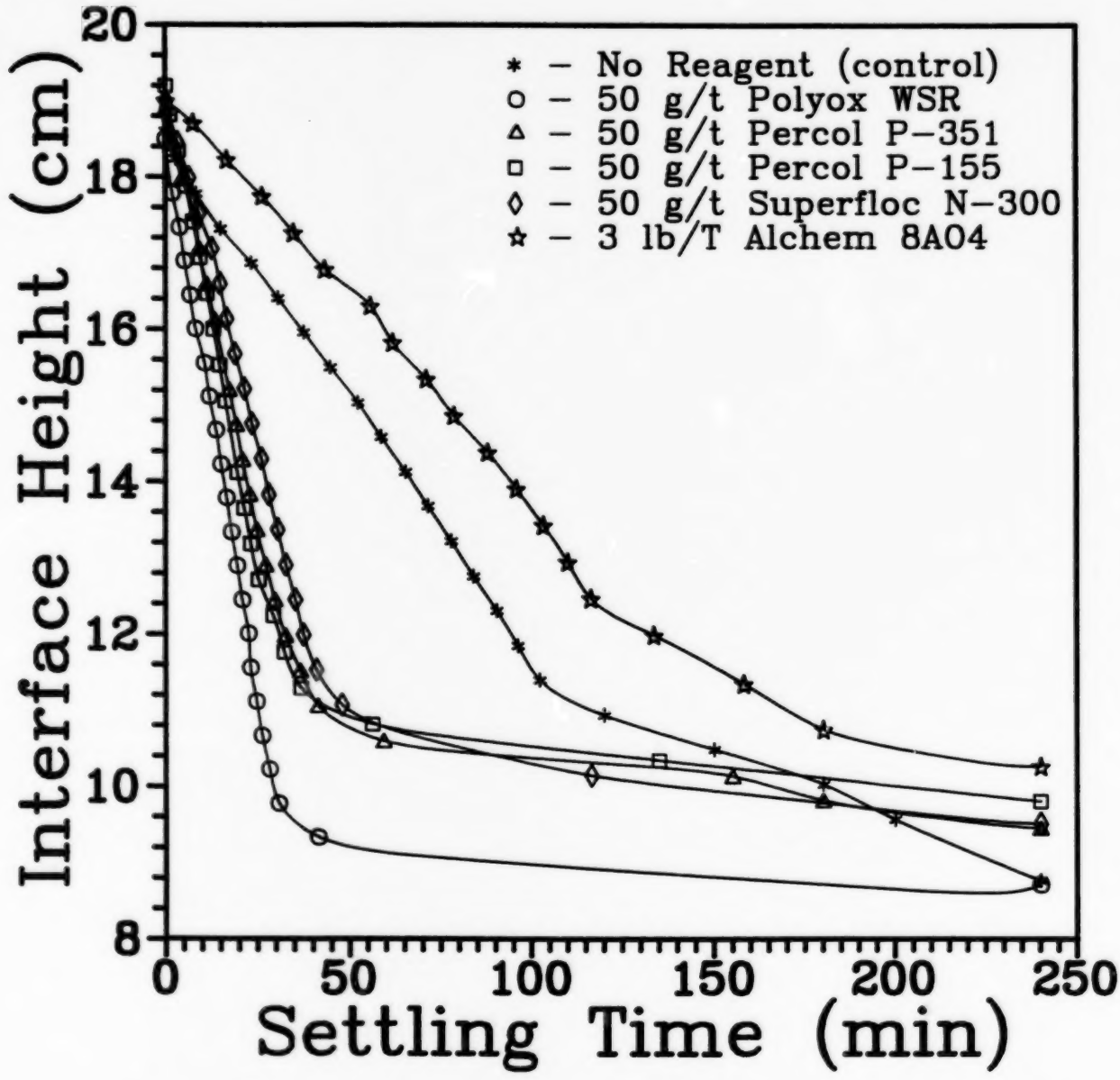


Figure 2. Settling Curves for Different Additives

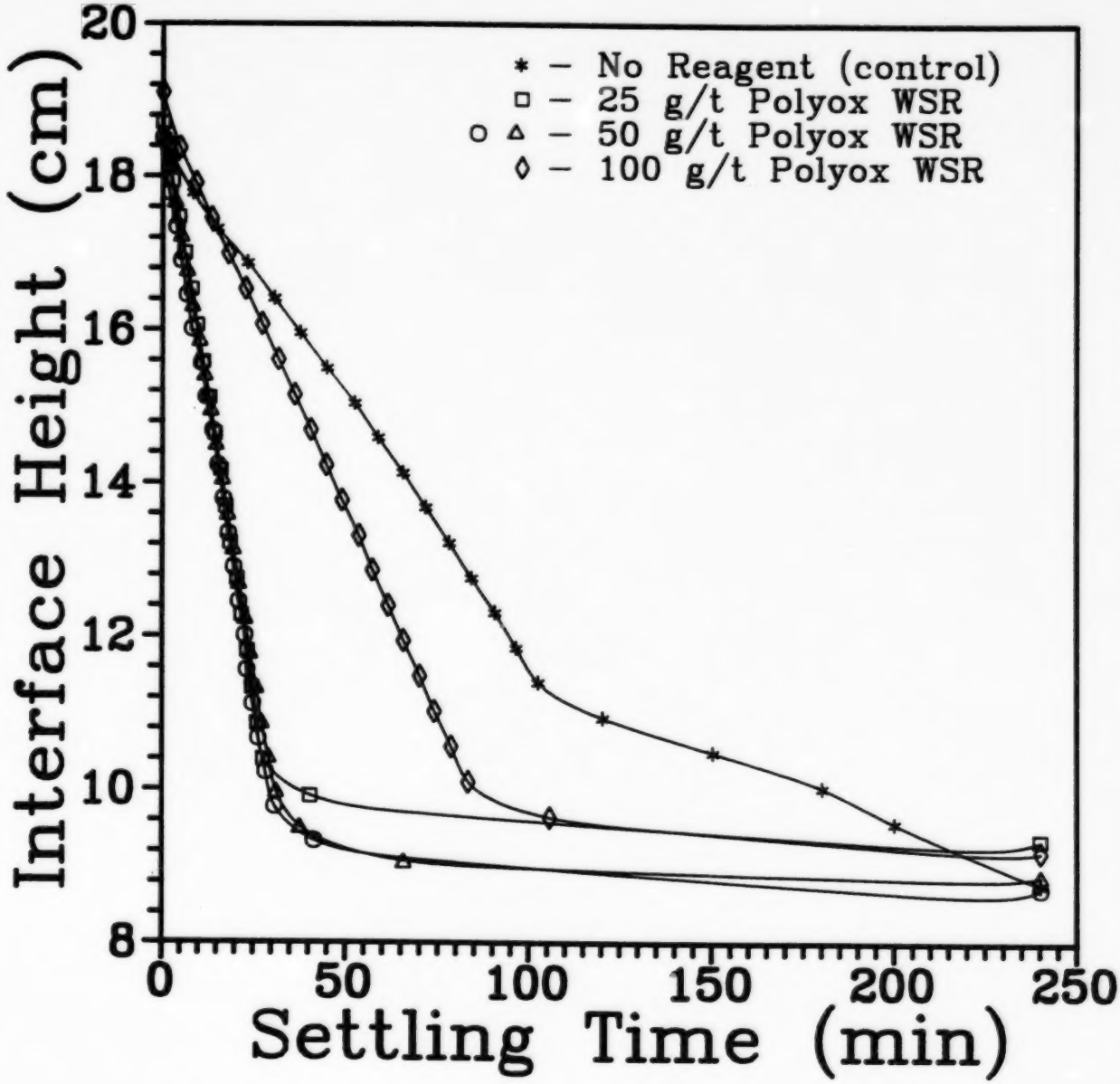


Figure 3. Settling Curves for Different Polyox WSR Dosages

ORGANIC LOSS BENCH TESTS

Economic advantages can be obtained by the use of solvent-in-pulp processing thus eliminating thickening and filtration steps in the treatment of leach slurry. Application is limited, however, by high organic losses due to intense emulsion formation and absorption of the organic phase onto the solid particles of the pulp. Mr. B.H. Lucas* and Mr. G.M. Ritcey* found from their experimental work that solvent losses in a uranium SIP process could be reduced by using some additives such as non-ionic proteins and carbohydrates, having hydrophilic properties, to such an extent that SIP processing became economically feasible compared with conventional thickener-filter and fixed-bed ion-exchange processes.

We have carried out some tests to determine the effects of various factors on organic losses in gold SIP process. According to the experimental method used by B.H. Lucas and G.M. Ritcey, we also determined the effectiveness of seven different surfactants in reducing organic losses. The test procedure and results are shown below.

From the results shown above we can draw some preliminary conclusions:

1. To our disappointment, none of the seven additives we have tried can reduce organic losses in gold SIP. We measured the viscosity, surface tension and contact angle of the raffinates, but did not find distinctive difference between them.
2. Whether organic is loaded with zinc or not is one of the principal factors affecting the organic losses. Organic loss is much lower when zinc loaded organic is used. In the clarified solution tests we also found that when fresh organic was mixed with alkaline cyanide solutions of gold, the raffinate became cloudy, showing that some organic had dissolved in the aqueous and been lost. We have experimentally compared the organic losses in water and in cyanide leach solutions. It was found that some organic did dissolve in the aqueous, but no remarkable difference was noticed

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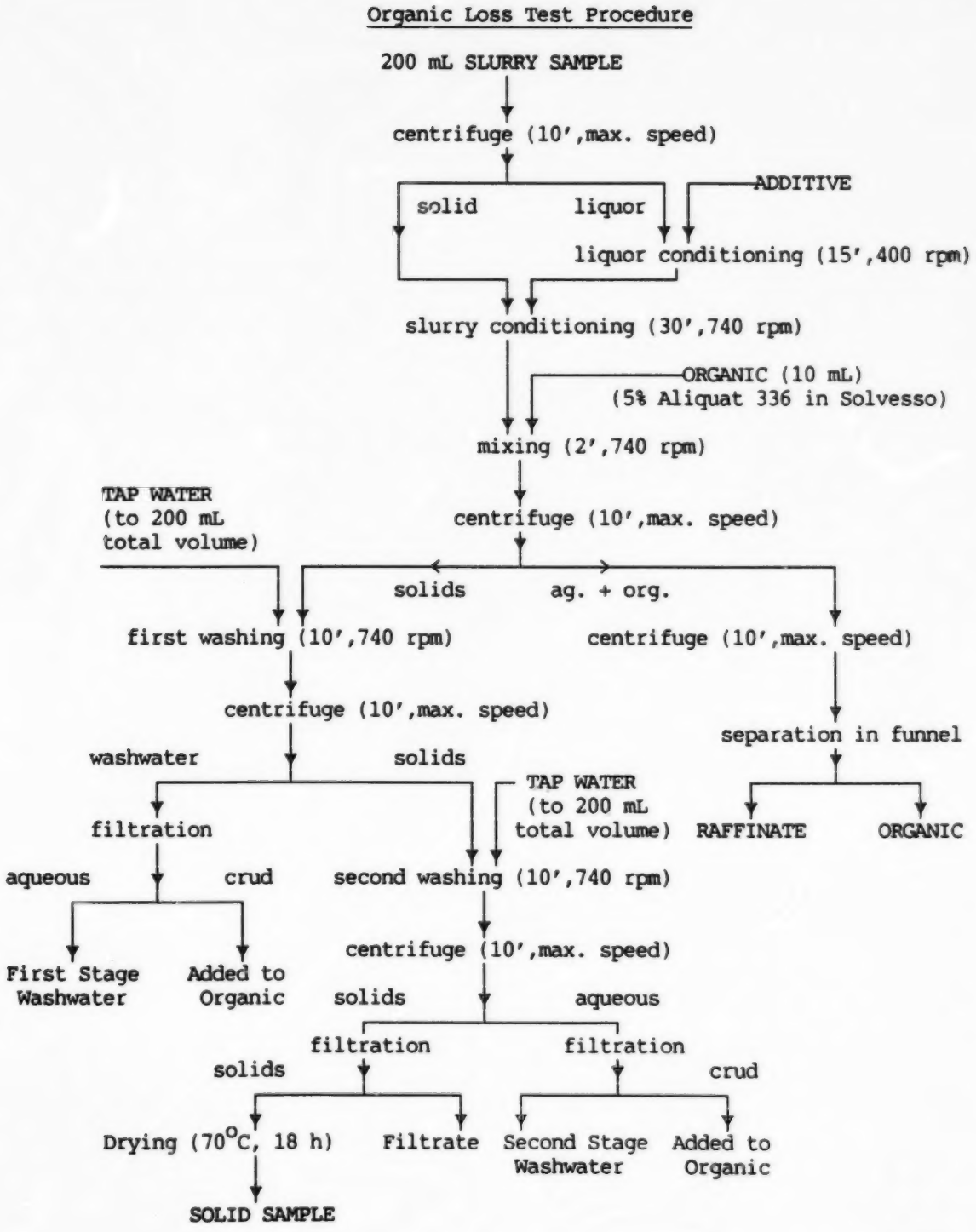
*B.H. Lucas and G.M. Ritcey, Use of Additives to Reduce Solvent Losses in a Uranium Solvent-in-Pulp Process, CIM Bulletin, 1-8, June, 1975.


Organic Loss Test Procedure
200 mL SLURRY SAMPLE
centrifuge (10',max. speed)
solid
liquor
ADDITIVE
liquor conditioning (15',400 rpm)
slurry conditioning (30',740 rpm)
ORGANIC (10 mL)
(5% Aliquat 336 in Solvesso)
mixing (2',740 rpm)
TAP WATER
(to 200 mL
total volume)
centrifuge (10',max. speed)
solids
ag. + org.
first washing (10',740 rpm)
centrifuge (10',max. speed)
centrifuge (10',max. speed)
separation in funnel
washwater
solids
TAP WATER
(to 200 mL
total volume)
filtration
RAFFINATE
ORGANIC
aqueous
crud
second washing (10',740 rpm)
centrifuge (10',max. speed)
First Stage
Washwater
Added to
Organic
solids
aqueous
filtration
filtration
solids
crud
Drying (70°C, 18 h)
Filtrate
Second Stage
Washwater
Added to
Organic
SOLID SAMPLE

Results of the Organic Loss Bench Test

Test	ADDITIVE	Raffinate Physical Properties			Organic Recovered (ml)	Crud (mL)	Dried Solid (g)	Total Amine		NOTES
		Viscosity	Surface Tension	Contact Angle				in Raff. (mg/l)	in Solid (mg/g)	
1	none	4.6	50.6	50.2	7.5	0.2	123.68		0.27	
2	fish glue 3 lb/T	9.65	51.2	49.3	6.5	1.2	123.16		0.25	
3	sugar 3 lb/T	-	50.75	53.7	7.0	0.8	133.92		0.22	
4	Polyox WSR 50 g/t	9.4	50.35	49.5	7.3	0.3	131.73	45	0.29	
5	Alchem 8A04 3 lb/T	10.3	49.7	53.7	7.7	0.4	122.03	40	0.32	
6	Aerosol GPG 3 lb/T	9.6	48.7	56.4	6.8	0.4	124.20		0.28	
7	none	9.3	43.8	58.0	6.6	0.1	121.75	52	0.42	
8	none	9.9	48.65	52.0	8.2	0	122.12	28	0.09	Zn Loaded Org.
9	Na_2CO_3 1.5 lb/T	10.0	46.0	53.6	7.1	0.1	126.38		0.43	
10	Na_2SiO_3 1.5 lb/T	9.7	46.9	57.5	6.9	0	125.16		0.45	
13	none	9.2	52.7		5.8	0.3	126.21	50	0.4	
14	none	9.25	55.1		7.8	0	123.99	12	0.2	Zn Loaded Org.
15	none	9.15	51.0		7.0	0.2	127.15	42	0.3	Mixing 745 rpm
16	none	9.4	50.1		8.2	0.2	127.30		0.4	Mixing 700 rpm
17	none	9.2	48.2		9.0	0	130.32		0.2	Mixing 400 rpm
18	none	9.4	45.5		9.4	0	126.01	65	0.1	Mixing 200 rpm
19	none	9.1	58.8		8.7	0	123.65	46	0.1	Zn Loaded Org.
20	Alchem 8A04 3lb/T	9.35	50.4		8.8	0	125.04	76	0.2	Zn Loaded Org.

between the organic loss in water and that in the cyanide solution. Besides we also found that by adding some alcohols to the organic as modifier, for example, isodecanol and 2-ethyl-1-hexanol, we could improve phase separation to some extent, but it could not reduce organic losses at all.

3. The other main factor affecting organic loss is agitation intensity. The more intensively the aqueous phase is mixed with organic, the more the organic is lost.

GOLD EXTRACTION KINETICS TEST

It has been proven in the tests above that organic loss increases with the mixing speed. In order to reduce organic loss the agitation has to be kept as gentle as possible. On the contrary, however, mixing intensity should be as high as possible to reach the equilibrium fast. The organic loss test demonstrated that the organic loss would be quite low when mixing speed was as low as 200 rpm. Therefore we did the kinetics test of gold extraction at this rotation speed using a clarified gold ore leach solution of Campbell Red Lake mine, gold content of which was much higher than that of the flotation tailings. The result of the kinetics test shows that the extraction speed is much slower than that at high mixing intensity. As is shown in the tests conducted by other colleagues in our section, a few minutes are enough to reach the equilibrium at high mixing speed.

The Result of Gold Extraction Kinetics Test

Phase ratio: 400/9 mL (aqueous/organic)
Mixing speed: 200 rpm
Temperature: room temperature (~25 C)

No.	Sample	Contact time	Au (ppm)	Extraction %
1	Feed	-	11.0	-
2	Raffinate	1'	7.2	34.1
3	"	2'	6.7	39.1
4	"	5'	5.5	50.0
5	"	10'	5.0	54.6
6	"	30'	2.1	80.9
7	"	60'	1.3	88.2

Gold Extraction Test Using Organic Different Aliquat 336 Concentrations

It is obvious that the amine loss will be reduced if the concentration of Aliquat 336 in the organic phase decreases, assuming that the total different mixing speeds and different contact time as shown in the table below.

Extraction Tests with Organic having Different Aliquat Concentrations

feed solution : Au 10.1 ppm

Test No.	Aliquat 336 %	Phase ratio A/O	Mixing Speed rpm	Contact Time min.	Raffinate Au ppm	Organic Recovered mL
1	5	200/2	730	2	3.2	1.45
2	5	"	200	2	8.4	1.50
3	1	200/10	730	2	3.7	9.4
4	1	"	200	2	7.9	9.4
5	1	"	730	30	3.5	9.35
6	1	"	200	30	5.9	9.6

From the results above we can see that the highest extraction is obtained when higher Aliquat 336 concentration (5%) is used, but almost the same good extraction can also be obtained at 1% Aliquat 336 concentration. At low agitation speed, however, better results will be obtained when organic containing low Aliquat 336 concentration is used at higher phase ratio and longer contact time. And we found total organic losses were almost the same whether a higher or lower phase ratio was used. From the viewpoint of organic losses it would be better to use an organic containing lower Aliquat 336 concentration at a higher phase ratio and at low agitation intensity.

PILOT PLANT TEST OF GOLD SIP IN A MODIFIED GRAESSER EXTRACTOR

According to the results of the tests, we decided to perform a SIP equipment test using a modified Graesser Extractor designed by Dr. R. Molnar. By the end of October 1987 we completed the installation of the test equipment and conducted a preliminary running test.

First we only fed the slurry to the extractor to see how the equipment worked. The test conditions were as follows:

Feed slurry: density: 40 w/o solids, flowrate: 300 mL/min.
Coagulant: Polyox WSR, concentration: 35 mg/L, flowrate: 15 mL/min.

It was found in the test that no clear aqueous layer was formed when only slurry was fed but when adding coagulant Polyox WSR mixed with feed slurry in a short section of a Kenics static mixer, solids settled rather fast in the lower section of the extractor and an interface between the aqueous and the thickened slurry could be seen. The underflow (raffinate slurry) became much thicker than the feed; the density of the underflow was more than 60%, depending on its outflow rate. When its flowrate was properly controlled, the interface could be kept at a certain position. The overflow, however, was not very clear, containing small amounts of fines.

Then we carried out a continuous equipment test for more than five hours by feeding both the slurry with coagulant and the organic (5% Aliquat 336 in Solvesso 150).

All together we fed about 95 litres of slurry and about 3 litres of organic. From the result of the first running of the equipment, we can say that physically the modified Graesser Extractor worked quite satisfactorily. There was no apparent emulsion occurring or crud formed because of the gentle mixing of the organic phase so organic losses seemed to be very low. The amine content in the raffinate aqueous (overflow) and in the raffinate slurry (underflow) have not been analysed, but no apparent organic loss could be seen in them by eye even after 48 hours settling. On the other hand, chemically, the modified Graesser extractor did not perform as well. Gold extraction was quite low, particularly in the underflow. Almost no gold had been extracted to the organic because the mixing was so weak that the organic had not contacted with the underflow. Now it has been planned to continue the SIP equipment tests to improve the gold extraction while maintaining the low organic losses.

CONCLUSIONS

Of course, half a year is not long enough to finish such difficult experimental work of gold solvent-in-pulp, which has not been carried out by other research workers as we know until now. From the test results we have had, I think the solvent extraction of gold from clarified leach solutions is very promising because of its high efficiency, high selectivity and high extraction rate. I am sure that it will be applied to the gold recovery from leach solutions under certain circumstances in the near future. As to the solvent-in-pulp of gold, up to now we have only made a first step, many difficulties have not be solved, there is still a long, long way to go before the SIP process can be used in gold hydrometallurgy.

ACKNOWLEDGEMENT

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